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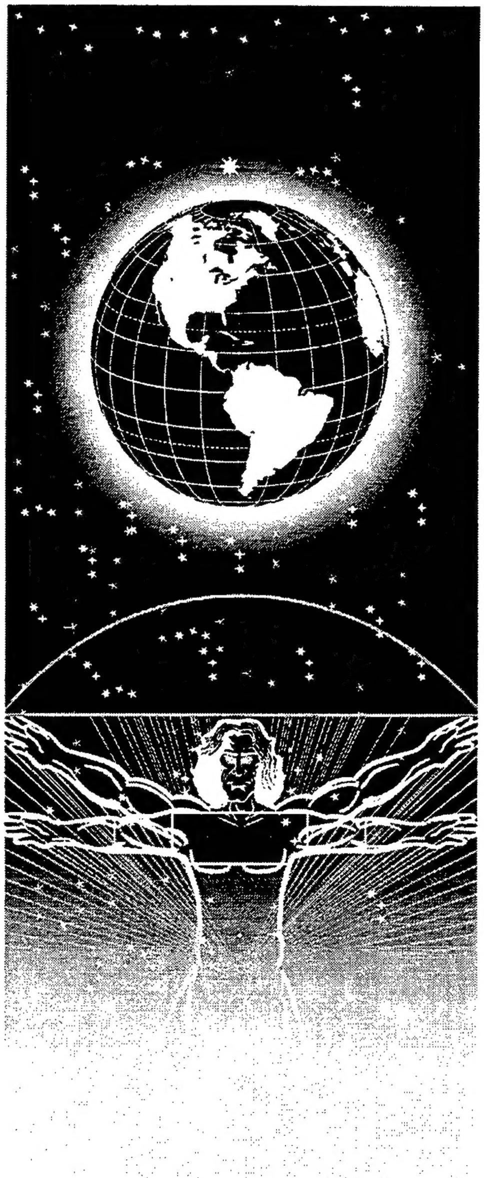

UNITED STATES AIR FORCE RESEARCH LABORATORY

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFOSR) 1999 ELECTROMAGNETICS WORKSHOP

Human Effectiveness Directorate
Directed Energy Bioeffects Division
8308 Hawks Road
Brooks AFB, TX 78235-5324

April 1999

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The Office of Public Affairs has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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This publication contains a collection of 28 abstracts of talks presented at the Tenth Annual AFOSR Electromagnetics Workshop, held 7-9 January 1999 in San Antonio, Texas.

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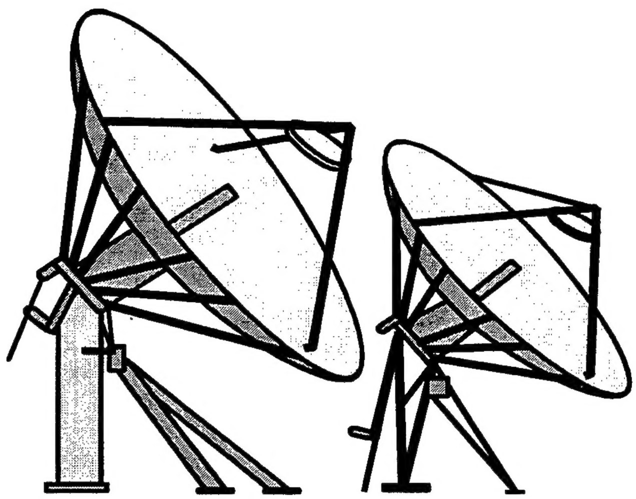

FOREWORD

This year's AFOSR 1999 Electromagnetics Workshop was the best ever. The abstracts contained in this document represent the collective efforts of our colleagues in the field of electromagnetics research. These abstracts were presented to over one hundred mathematicians, scientists, and engineers at the Tenth Annual Electromagnetics Workshop held in San Antonio, Texas on the 7-9 January 1999. The attendees represented government, industry, and academia. The high quality of this year's workshop can be attributed to the expert knowledge of the speakers.

The AFOSR Electromagnetics Workshop started as a small, informal group meeting to address a need to have accurate models of electromagnetic propagation, including short pulse propagation. It has grown over the years to a nationally recognized event bringing together this country's foremost authorities in electromagnetics studying propagation models relevant to military operational problems, such as scattering from non-penetrable (highly reflective) missiles or aircraft, or from penetrable surfaces such as radar absorbing materials.

The success of the AFOSR 1999 Electromagnetics Workshop is due to the untiring efforts of the Workshop committee members and to Dr Arje Nachman, sponsor of the annual workshop. The following personnel are recognized for their efforts in supporting and organizing this workshop:

Dr Arje Nachman	Air Force Office of Scientific Research, Mathematics and Space Sciences Directorate, Arlington, VA

Mr George Page	Air Force Research Laboratory, Human Effectiveness Directorate, Directed Energy Bioeffects Division, Brooks AFB, TX
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Dr Richard Albanese	Air Force Research Laboratory, Human Effectiveness Directorate, Biomechanisms & Modeling Branch, Brooks AFB, TX
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Dr Sherwood Samn	Air Force Research Laboratory, Human Effectiveness Directorate, Biomechanisms & Modeling Branch, Brooks AFB, TX
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Plasma Filled Radial Acceleration

M. Joseph Arman
AFRL/DEHE
Kirtland AFB, NM

The advantages of the Radial Acceletron over conventional sources has been reported by Arman(1). Briefly, the radial structure of this design allows for much smaller impedances and thus higher powers, the growth rate is large because of the transit-time nature of the interaction, and the source is compact because there is no need for external magnetic fields. Adding plasma to the interaction region of certain high power microwave sources has had beneficial effect on the growth rate and efficiency. We believe the Radial Acceletron will also be enhanced by the presence of positively charged plasma in the main cavity. Here I report on the results of adding plasma to the Radial Acceletron. The research is carried out numerically by simulation, using the particle in cell (PIC) codes, magnetic insulation code (MAGIC), and self optimizing sector (SOS). The plasma enhanced Radial Acceletron can possibly generate gigawatts of coherent radiofrequency power in a wide range of frequencies.

(1) "Radial Acceletron, a New Low Impedance HPM Source", IEEE Transactions on Plasma Science, Vol. 24, No. 3, June 1996, Special Issue on High Power Microwave Generation

On The Construction of a High Order Difference Scheme For Complex Domains in a Cartesian Grid

Amir Yefet
New Jersey Institute of Technology
Mathematical Sciences Department
University Heights, Newark, NJ

We consider fourth order accurate compact schemes for the numerical solutions of the two dimensional Maxwell equations. We base this scheme on Ty (2,4) scheme[1]. We solve the equations on a Cartesian mesh but consider boundaries, which do not necessarily conform with the Cartesian grid. On the boundaries we use second or third order accurate approximations.

[1] \bibitem{Ty} E. Turkel and A. Yefet, \emph{Fourth Order Accurate Compact Implicit Method for the Maxwell Equations}, to appear

Advances in High-Order Time-Domain Methods for CEM

David Gottlieb
Brown University
Division of Applied Mathematics
Providence, RI

We shall discuss a number of developments in file continued effort for formulating, implementing and evaluating high-order accuracy methods, and in particular spectral methods, for the time-domain solution of Maxwell's equations in geometries and materials.

A special emphasis shall be put on a discussion of certain types of weak instabilities recently discovered in unsplit well-posed perfectly matched layer (PML) methods. The instabilities are a potential source of problem in situations such as long time integration of pulsed problems or when using very accurate schemes in total-field/scattered field computations. The weak instability is associated with the system of ordinary differential equations often introduced in unsplit PML methods and we shall present a number of examples of the phenomena and its resolution.

In what remains we shall briefly discuss various other recent developments in high-order time-domain methods for computational electromagnetic (CEM), such as detailed verification studies of the spectral multi-domain scheme for electromagnetic code consortium (EMCC)-Benchmarks on pure scattering and parallel implementations and efficiency of the spectral multi-domain framework. We shall also briefly discuss the development of a 4th order staggered scheme which avoids staircase approximations of curved boundaries, hence dramatically enhancing its overall accuracy.

Progress Towards Building an Efficient, Electrically Small Compound Antenna

Craig A. Grimes
University of Kentucky
Dept of Electrical Engineering
Lexington, KY

Use of the time domain Poynting theorem shows that standing energy fields local to certain multi-element antennas can be either partially or completely cancelled by selective control of individual element amplitude and phase with respect to the other antenna elements. Our work is focused on seeing if such antennas can be experimentally realized. To extend our analytical base, we have determined the radiation Q of these electrically small, multi-element antennas a new way. Working in the time domain, the radiation source is turned off and the power which returns to the antenna determined. A time integral of the power that returns to the antenna is put equal to the standing energy that was about the antenna when it was driven. The time average output real power of the antenna before shut off is determined by integrating the power density over an enclosing virtual sphere, allowing the radiation Q to be determined. The technique provides a direct method for time domain determination of Q for electrically small, multi-element antennas. Our results for electrically small, multi-element antennas will be discussed. The most interesting compound antenna design consists of four elements radiating equal power levels; two transverse electric (TE) and two transverse magnetic (TM) dipole sources. The two TE sources are phased to support circular polarization, as are the two TM sources; there is an absolute phase difference between the TE and TM sources of ninety degrees. For this design, theory shows that the standing energy that returns to the antenna upon shut down is zero, and Q for the source is zero. Initial attempts toward implementing this design has shown that the symmetry of the sources leads to unwanted coupling, where the power radiated from one element is simply absorbed by another. A summary of our experimental results will be presented.

Focused Application Software for the Design of Ferrite Focused Patch Antennas

Keith Trott
Mission Research Corp
Valparaiso, FL

Ferrite materials exhibit dispersive properties manipulated by adjusting the strength and orientation of a static magnetic bias field; that is, the material "looks" different to a dynamic field as the static "control" field is altered, enabling many novel applications of ferrite patch antennas.

This is a collaborative effort between Mission Research Corp (MRC), University of Michigan, and Electromagnetic Applications (EMA) to develop computational electromagnetic (CEM) tools capable of modeling the radiation properties (pattern, input impedance, efficiency, and bandwidth) of conformal arrays printed on ferrite substrates and superstrates. Capabilities include modeling inhomogeneous ferrites and dielectrics, non-planar surfaces, heterogeneous elements, complex feeds, and performance control devices such as shorting pins and lumped loads. These codes will be combined via a Graphical User Interface (GUI) into a user-friendly code capable of modeling conformal patch antennas with ferrite substrates and superstrates. This project couples calculation and measurement in an effort to validate the CEM tools developed. The basic tasks include:

- Develop Finite Element Method (FEM) Analysis Engines
- Build on Finite Element-Boundary Integral (FE-BI) and FE-Perfectly Matched Layer (FE-PML) FEM codes
- Enhance LM_Brick-based Ferrite (FE-BI) code
- Develop Prism code
- Develop Tetrahedral code
- Incorporate High Order Elements (HOE) and fast integral techniques
- Code Validation
- Fabricate and measure ferrite antennas
- Compare calculations with measurements
- Explore ferrite antenna capabilities
- Integrate FEM codes with Graphical User Interface (GUI)

We will highlight successes by the research team on this program and discuss the impact of these tools and their improvements for performing

engineering design studies for ferrite patch antennas. Ferrite patch antennas and antenna arrays have the potential to solve many real Air Force problems.

Mathematical Aspects of Biological Effects of Electromagnetic Fields

Richard A. Albanese and Richard L. Medina
AFRL/HEDB
Brooks AFB, TX

Electromagnetic fields are being increasingly used in our technological society. We believe that a formal electromagnetic radiation biology will develop as it has for X-rays, gamma rays, neutrons, alpha, beta and other high-energy particles. Mathematics will play an important role in electromagnetic radiation biology as it has in the classical radiobiology of waves and particles with high energy per quantum. We set out areas of mathematical research in this brief discussion. Key statistical questions are outlined, an unusual model of cellular damage following Bross is sketched, an issue of membrane depolarization is described, and the importance of reaction diffusion equations and elasticity theory is portrayed.

Electromagnetics Basic Research Program of the Army Research Office

James F. Harvey and James W. Mink
U.S. Army Research Office
Research Triangle Park, NC

An overview of the Army Research Office (ARO) 6.1 program in electromagnetics (EM) will be presented. The ARO program has concentrated in issues 1.) of spatial power combining, and innovative microwave and millimeter wave circuit integration techniques; 2.) of radio wave propagation near complex terrain, novel approaches to EM computations, small / multi-functional antennas for tactical radios, and mine detection and 3.) of low power radiofrequency (RF) applications. Key technical issues in each of three technical areas will be discussed, along with major accomplishments and future directions.

Target Detection and Identification Using UWB Antenna Arrays

Tony Devaney
Northeastern University
Dept of Electrical & Computer Engineering
Boston, MA

The problem of detecting, locating and identifying scatterers from UWB scattering data is solved using a maximum likelihood approach within the framework of exact scattering theory. The theory and developed algorithms apply to an arbitrary number of transmitting and receiving antennas that are arrayed over an arbitrary set of points in three-dimensional space. Specific application of the theory to radar probing of scatterers embedded in dispersive backgrounds is presented.

Spectral Changes Produced by Particle Scattering and Generalized Holography

Emil Wolf
The University of Rochester
Department of Physics & Astronomy
Rochester, New York

In the first part of this talk a new method will be described for deducing the structure function of a random distribution of particles from the analysis of spectral changes which are generated when polychromatic light is scattered by the particles. In the second part the possibility will be discussed of storing and recovering correlation functions of fields of arbitrary state of coherence by the use of a technique somewhat similar to holography. The method could be used, for example, to determine correlation functions of random media from scattering experiments, using the technique of diffraction tomography.

Solving Maxwell's Equations from Zero Frequency to Microwave Frequencies

W.C. Chew and J.S. Zhao
University of Illinois
Dept of Electrical & Computer Engineering
Urbana, IL

Maxwell's equations decouple into magnetostatic and electrostatic fields right at zero frequency. As a consequence, many Maxwell solvers written for electrodynamics fail to work correctly at zero frequency. It can be easily shown that the decoupling of the electric and magnetic fields at zero frequency forces the current to be decomposed into a curl-free part and a divergence-free part, but with disparate amplitudes at very low frequencies. Therefore, a Maxwell solver where the integral equation is solved in terms of the unknown current, a Helmholtz decomposition of the current is necessary to facilitate a stable solution all the way down to zero frequency. The prevailing method is to use the loop-tree and loop-star treatment. However, these treatments alone remove the problem of disparate amplitudes in the two types of current, but they still give rise to ill-conditioned matrices. These ill-conditioned matrices still require a large iteration count to solve when iterative solvers are applied to their solutions. In this talk, we suggest a preconditioner based on a connection matrix to reduce the ill conditioning of the Helmholtz decomposed system. As a consequence, the iteration count is greatly reduced when iterative solvers are applied to solve the resultant matrices.

Optimal Design of Periodic Dielectric Structures

David Dobson
TX A&M University
Dept of Mathematics
College Station TX

We discuss recent progress in the modeling and optimal design of periodic dielectric structures. This includes discussion of a homotopy algorithm for producing bandgap structures from initial guesses with no band gap, a method for optimal design of 2D bandgap structures in H-

parallel polarization, and preliminary work on an efficient method for 3D band structure calculations.

1D/2D Obstacle Problems, High-Frequency Approximations, and Geodesics

Vladimir Oliker
Matis Inc.
Atlanta, GA

Solutions of radiation and coupling problems for antennas on aircraft, ships, satellites, etc. by high-frequency methods often relies on simplified platform geometry representation as an assortment of simple shapes such as cylinders, ellipsoids, plates, etc. The availability and faithfulness of flat-faceted, non-uniform rational B-spline (NURBS), and other computer aided design (CAD)-generated models of numerous military and civilian platforms makes it important to consider whether the utility range of these models can be extended to include support of analyses of radiation and coupling problems. The constructions of Geometric and Uniform Theories of Diffraction (GTD and UTD, respectively) do not depend, in principle, on a specific surface representation (as long as the surfaces are smooth outside of specified edges, corners, and, possibly, other electromagnetically significant singularities). However, an actual numerical implementation of this approach for CAD-generated models requires solution of very non-traditional and quite challenging geometric problems (resembling the obstacle problems for minimal surfaces). In addition, typical CAD surface models have various geometric singularities that have to be recognised and distinguished from electromagnetically significant singularities.

In this talk we will discuss some of the geometric and electromagnetic issues related to this circle of ideas and will describe some of the work in this direction.

An Outlook of CEM Multidisciplinary Applications

J.S. Shang
AFRL/VAA
WPAFB, OH

Advances in the tier-structured computational electromagnetics for scattering, antenna, and coupling applications are assessed for future research. However, a special emphasis is focused on the most recent progress made in the time-domain methods. In the development of the interdisciplinary technology development for aerospace science, a breakthrough potential of combining electromagnetics, aerodynamics, and chemical kinetics for hypersonic wave drag reduction is highlighted. The basic formulation of magneto-aerodynamics and pertinent science issues are delineated.

A Finite-Difference Method for Dispersive Waves in Homogenous Materials

Jonathan Luke
New Jersey Institute of Technology
Dept of Mathematical Science
Newark, NJ

For linear hyperbolic systems with constant coefficients, there are finite difference schemes that are exact when applied to polynomial initial data of a given order. Applied to general data, these schemes are often high-order and stable for problems involving propagation of electromagnetic waves in dispersive media. For scattering problems and propagation in inhomogeneous media there are natural extensions of these schemes retaining many of the advantages of the homogeneous case. We discuss these extensions and issues associated with their implementation.

Numerical Analysis of an Integral Equation Arising from Electromagnetic Interior Scattering Problems

Sherwood Samn
AFRL/HEDB
Brooks AFB, TX

Solving interior scattering problems of electromagnetic waves in biological media using a volume integral equation approach gives rise naturally to an integral equation of the third kind with unbounded coefficient and with a singular kernel slightly more severe than a weakly one. It is well known that the concept of collectively compact operators [Anselone] can be used to prove the convergence of various Nyström methods for solving integral equations of the second kind with weakly singular kernels. We will discuss conditions under which the same is true for the case in question.

Application of Symmetry to Magnetic-Singularity Identification of Buried Targets

Carl E. Baum
AFRL/DEHP
Kirtland AFB NM

A common class of buried targets has CN symmetry (N-fold rotation axis) for N>3. This makes the magnetic-polarizability dyadic decompose into longitudinal and transverse parts, each with its own natural frequencies (pure exponential decays in time for magnetic-singularity identification characterised by diffusion in metal). This increases the number of aspect-independent parameters by including the ratios of the pole residues within each of these two parts. With appropriate three-axis coils (transmit and receive) above the ground surface, one can make measurements, which can be used to locate and orient (modulo sign on rotation axis) the target. This involves moving the coils above the ground and orienting the coils so as to find certain nulls in the data. A procedure (algorithm) is developed for this purpose.

Nonreciprocal Periodic Dielectric Media

Alex Figotin
University of California at Irvine
Dept of Mathematics
Irvine, CA

A medium is called nonreciprocal if the time reversal symmetry is violated. In the case of dielectrics such media is often called magnetoelectrics. For these media there is a linear coupling between magnetization and polarization. A remarkable feature of a magnetoelectric medium is that the propagation speed of electromagnetic waves can be different for two opposite directions. It turns out that if magnetoelectric effect is combined with periodicity of the medium the dispersion relations develop unusual features. In particular, the waves of different frequencies can have preferred propagation directions. We give a thorough study to the nature of this phenomenon based on the Lagrange and Hamilton methods and apply the results to the simplest possible systems of this kind which turn to be nonreciprocal periodic electric circuits involving so-called gyrators (Tillegen nonreciprocal elements). For these systems the dispersion relations, the group and energy velocities are studied in detail as functions of the medium parameters. In particular, the obtained results show how one can manipulate the propagation direction of the electromagnetic energy.

Electromagnetic Modeling Of Complex Geometries

John J. Ottusch & Stephen M. Wandzura
HRL, LLR
Malibu CA 90265

HRL has recently started work on an AFOSR contract to develop, implement, and test improved numerical techniques for fast, high-order EM modeling of complex geometries. We will outline the objectives and approach of this work and present preliminary results.

Influence Of The Precursor Fields On Ultrashort Pulse Measurements

Hong Xiao & Kurt E. Oughstun
University of Vermont
College of Engineering & Mathematics
Burlington, VT

The influence of the precursor fields that are characteristic of a double resonance Lorentz model dielectric on ultrashort pulse autocorrelation measurements and frequency resolved optical gating traces is presented. A comparison with numerical results obtained in the group velocity approximation shows the profound effect produced by the precursor fields on these two ultrashort pulse measurement methodologies.

On the Discretization of Integral Equations of Scattering Theory

Vladimir Rokhlin
Yale University
Dept of Computer Science
New Haven, CT

The original goal of the project was to investigate algorithms for the discretization of band-limited functions on surfaces, especially in the high-frequency regime. To this effect, we have constructed optimal (in a very strong sense) discretizations of intervals on the line, of discs in the plane, and of triangles in the plane. For intervals and discs, the underlying theory is a fairly straightforward extension of classical results by Slepian et al.; for triangles in the plane, it involves a certain amount of new mathematics. Two papers reporting these developments are in preparation, and we are investigating possible hardware applications of the approach.

While constructing the analytical apparatus for the descretization of band-limited functions, we observed that the theory (at least in one dimension) applies to functions with surprisingly general singularities, opening the possibility of extending some of the spectral methods to environments that have been previously closed to them. A preprint has been released reporting these results in one dimension, and we are presently attempting to extend them to functions in the plane.

Advancing the Frontiers of Time-Domain CEM for X-Band Applications

Vijaya Shankar, Chris M. Rowell, Adour Kabakian and William Hall
HyPerComp, Inc.
Westlake Village, CA

The large size of far-field radar ranges poses a serious problem for any numerical method that seeks an accurate solution to Maxwell's equations for the fields scattered back to the radar from the vicinity of the target and its supporting structure. Even compact ranges are typically an order of magnitude larger in every dimension than the targets they measure, so that the number of unknowns required for direct numerical solution is two to three orders of magnitude larger than that for the target alone. Since numerical techniques have only recently advanced to the point where the radar cross-section (RCS) of an isolated low observable (LO) aircraft can be accurately computed at wavelengths shorter than one meter, it is clear that a considerable improvement in solution methods will be required.

The approach taken in the current effort treats separately the processes of radiation from the source radar, propagation over the range, scattering from the neighborhood of the target, and propagation back to the radar. A unique, general 3D solver for Maxwell's equations in the time domain has been developed to determine the scattered fields. This solver is almost ideally suited for massively parallel computing platforms, exhibiting linear speedup over two orders of magnitude in the number of processors used.

The specific application driving this research has been the continuing effort to improve the capabilities of the radar target scatter (RATSCAT) advanced measurement system (RAMS) radar range at Holloman Air Force Base in New Mexico. Especially for low observable (LO) targets at frequencies below 600 MHz, there is concern that interactions among the target, its support, and the surrounding range modify the target return to a significant extent. To address this concern, the 46th Test Group at Holloman is pursuing a number of experimental approaches, including the use of a specially designed LO target.

Numerical simulation of the range offers a way to compare the benefits of these different approaches, and to explore effects within a wide range of experimentally accessible conditions. Quantitative studies can reveal the

best directions for redesign of the target support or the presence of unwanted effects due to modifications of the range profile.

The particular approach developed in the research reported here employs explicit time integration in a finite-volume framework for an unstructured grid [1]. This method, which draws heavily on the foundations of similar techniques current in computational fluid dynamics, is an outgrowth of ongoing work at the Rockwell Science Center on time-domain computation of radar scattering from isolated targets [2].

The continuing maturation of time-domain CEM technology embraces activities that broadly fall into two categories. 1) Demonstration of demanding cases which include computing RCS and synthetic aperture radar (SAR) imagery of any target shape (missile, ships, aircraft, etc.) with or without material treatment as well as radiation problems for antennas in the presence of other structures; and 2) Development of advancements in CEM technology such as grid enhancement, accuracy improvements, parallel code optimization and user friendly graphical interface (GUI), all of which critically support the demonstration tasks. The primary focus of this paper is on maturing the time-domain CEM technology for ATR applications all the way from low frequencies (~1GHz) to X-band (~10GHz).

The UPRCS time-domain CEM code has the following attributes that make it very attractive for satisfying Air Force requirements in SAR imagery.

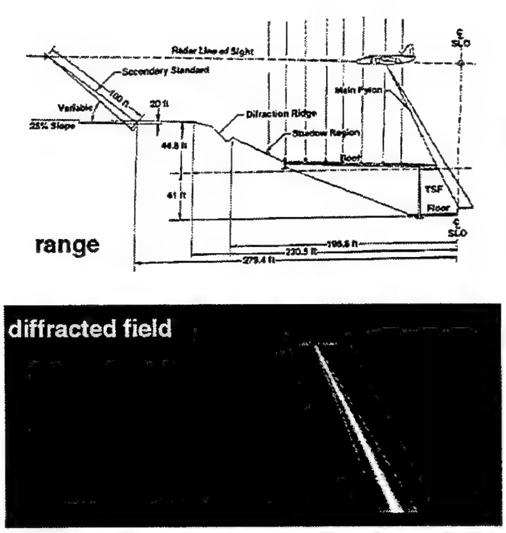
1. Solution to time dependent Maxwell's equations are obtained using high order time and space discretization
2. The approach includes general material treatment such as resistive cards, dispersive and anisotropic media, and impedance layers
3. The finite-element-like-finite-volume approach of UPRCS allows for local special solutions for thin wires, gaps, cracks and sharp edges
4. Includes both pulse (broadband) and continuous wave (CW) (single frequency) excitation
5. Provides both frequency domain farfield (RCS) and time domain farfield (range profile) outputs
6. Very scalable code architecture for workstation cluster and parallel platforms using message passing interface (MPI) message passing libraries

The unstructured parallel radar cross section (UPRCS) code scales very well on workstation clusters and large-scale parallel platforms. It is feasible to extend the UPRCS computations to X-band range on realistic configurations such as the C29, VFY-218 and the SLICY model. Following table shows the resource requirements.

Frequency (GHz)	Total # of Cells	# of Cells/Node	# of Nodes	Time for ATR Simulation
2	2-3 Million	40,000	64	30 minutes to 1 hr
4	5-6 Million	40,000	128	30 minutes to 1 hr
8	10-15 Million	100,000	128	2-4 hrs
12	30-40 Million	150,000	256	2-4 hrs

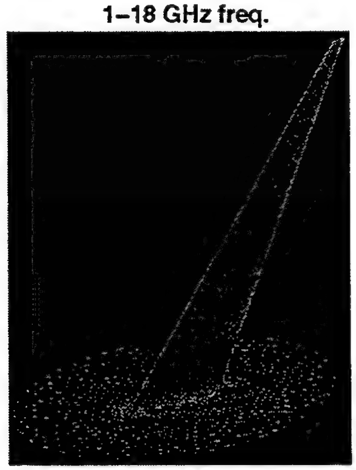
The application of UPRCS for the RATSCAT range problem will be presented.

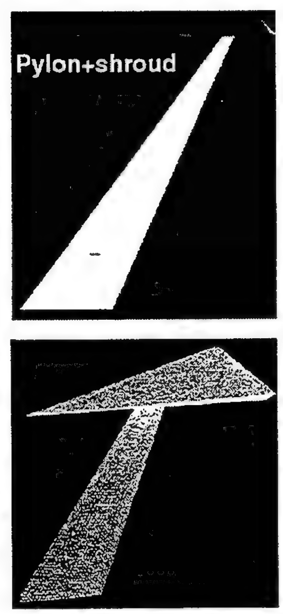
UPRCS Application - Outdoor Range Simulation



Outdoor Range – 100 MHz to 1 GHz

14' Pylon
1–18 GHz freq.





1. Rowell, C., Shankar, V., Hall, W. F., and Mohammadian, A., "Algorithmic aspects and computing trends in computational electromagnetics using massively parallel architectures," presented at the First IEEE Conference on Algorithms and Architectures for Parallel Processing, Brisbane, April, 1995

2. **Mohammadian, A. H., Shankar, V., and Hall, W. F., "Computation of electromagnetic scattering and radiation using a time-domain finite-volume discretization procedure,"** ***Computer Phys. Comm.*** **68, 175 (1991)**

High Order Methods in Computational Electro Magnetism

Oscar Bruno
Caltech
Applied Mathematics
Pasadena, CA

An overview will be presented of a variety of new techniques in computational electromagnetism. These include perturbative methods for scattering and eigenvalue problems, new integral volume and surface scattering solvers in two- and three dimensions, as well as new high frequency integral approaches. Amongst the applications we will mention computation of EM scattering from the ocean, evaluation of scattering from penetrable bodies, solution of problems involving imperfect conductors by means of new integral high-frequency perturbative methods, surface integral methods in 3-D, etc.

Development of Computational Electromagnetics for Solving Scattering, Radiation and Electromagnetic Environmental Problems

Ramesh K. Agarwal
Wichita State University
National Institute for Aviation Research
Wichita, KS

A compact higher-order finite-volume time-domain method has been developed for solving the Maxwell equations on unstructured grids to compute the electromagnetic wave scattering by two-dimensional heterogeneous objects. Further simplification is obtained for harmonic incident waves by transforming the solution space to the frequency-domain. A pseudo-time concept is introduced for solving the frequency domain equations using the time-domain algorithm. Higher-order formulations are

based on both the derivative method and the moment method employing discontinuous piecewise polynomial reconstruction. The discrete equation set is integrated in the time- or frequency-domain using an explicit four-stage Runge-Kutta scheme. A point-implicit calculation of the real-time term is employed to relieve the stiffness of the frequency-domain equation set. A novel treatment of the radiation boundary condition, based on the similarity form of the Maxwell equations, is employed to minimize the size of the computational domain. Material interface boundary conditions are explicitly enforced using a local modified integral equation approach. The preliminary calculations have been performed by the moment method to compute the transverse electric (TE) scattering from a perfectly conducting (PEC) circular cylinder.

Absorbing Boundary Conditions and Numerical Dispersion

Peter Petropoulos
New Jersey Institute of Technology
Dept of Mathematical Science
Newark, NJ

Predictions of performance of both exact and approximate Absorbing Boundary Conditions (ABCs) do not take into account the fact that in an actual simulation it is numerical rather than analytical waves that are incident on the computational domain boundary. Via a model problem in rectangular coordinates we identify and frame this issue. Then, we study the reflection produced by discrete local ABCs in cylindrical coordinates using as a model the Bayliss-Turkel operator. We find that the analytical reflection coefficient of the ABC significantly underestimates the actual reflection on the grid, and that the additional error decays slowly with increasing resolution. Also, the impact of numerical dispersion on the performance of the discrete perfectly matched layer will be discussed.

New Results on Complex Source Pulsed Beams

Gerald Kaiser (work done jointly with Ehud Heyman)
The Virginia Center for Signals & Waves
Glen Allen, VA

Complex Source Pulsed Beams (CSPB) are exact, causal solutions of the wave and Maxwell equations obtained by extending the retarded Green functions to complex space-time. Thus they represent, formally, the fields emitted by a point source with complex space-time coordinates. This is a very compact way of describing pulsed beams radiated by a circular aperture in *REAL* space whose center, radius, orientation, launch time, and pulse duration are determined by the assumed complex source coordinates. But it cannot be realized literally because it is impossible to place a point source at complex space-time coordinates. We construct an equivalent source *DISTRIBUTION* (no longer a single point) which yields the CSPB solutions exactly. This source distribution is a generalized function concentrated on the (physical) aperture emitting the beam, and when the source coordinates become real, it contracts to the original point source giving the retarded Green function. We propose that it may be possible to realize CSPB in practice using such real source distributions. This should be very useful, given the many ideal properties of such beams.

A New Eularian Method for Capturing the Motion of Electromagnetic Pulses

Steven Ruuth
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To approximate the propagation of waves in the geometrical optics limit, a variety of methods have been proposed. Lagrangian methods can become quite complicated because cells must be adaptively added and deleted to achieve stable, accurate results. Standard Eulerian methods, however, are designed to treat merging fronts and thus do not allow waves to pass through one another.

To achieve an Eulerian formulation appropriate for wave propagation,

J. Steinhoff, M. Fan and L. Wang recently proposed Dynamic Surface Extension (DSE) Methods. In this talk, we discuss a new DSE-Scheme which uses first arrival times to extend the surface representation onto a uniform mesh. Methods for the reflection, refraction and the curvature-dependent motion of fronts are discussed. A simple method for propagating intensity values is also given.

Adaptive hp-FE Modeling for Maxwell's Equations

Leszek Demkowicz
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This is a progress report on the development of the *hp* Finite Element Method for steady-state Maxwell's equations in both interior and exterior domains. The presentation will touch on a number of theoretical and implementation issues, including: Convergence analysis for eigenvalue problems, implementation of constrained approximation (*h* refinements), implementation of infinite elements, a two-grid interactive solver, a parallel implementation on Cray 3TE.

Wavelet Based Numeric Methods for Wave Propagation

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Homogenization is an analytic tool for simplifying mathematical models with different scales. Very special material structure is needed for this process to be applicable. We introduce a numerical homogenization technique which applies to a more general class of problems. A differential equation which is discretized is the starting point. The dimension of this discretized operator is then reduced by projecting onto courser wavelet spaces. Important properties of wavelets keep the discrete operators sparse.

The technique is applied to electromagnetic problems in frequency domain. We consider the case when the overall scale of the problem and the

wave length is much larger than some small geometrical details. The numerical homogenization results in a discretization with a courser mesh size than the small geometrical details. The effect of these details is, however, contained in the solution. Numerical tests from electromagnetic compatibility are given.

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Hope to see you in 2000!

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